3.6 Electromagnetic Fields and Electromagnetic Interference

This section describes the potential impacts of electromagnetic fields (EMFs) associated with operation of the No Project and the HST Alignment Alternatives[1]. **The principal topics discussed in this section are potential impacts on personal health and potential impacts on electronic and electrical devices as a result of electromagnetic interference (EMI).**

3.6.1 Regulatory Requirements

Neither the federal government nor the State of California has established regulatory limits for EMF exposure. The Federal Communications Commission (FCC) regulates sources of radiofrequency (RF) fields to maintain the quality of wireless communications across the spectrum. The FCC, which does not regulate for health and safety, has adopted regulations applicable to EMF exposure that were derived from health and safety evaluations made by the American National Standards Institute/Institute of Electrical and Electronic Engineers (ANSI/IEEE) and the National Council on Radiation Protection (NCRP). FCC regulations apply to devices that produce RF radiation, such as the proposed HST wireless systems, for both operational and amenity purposes. FCC regulations otherwise apply only if HST operations (RF interference) interfere with legitimate spectral uses.

Voluntary standards for EMF exposure have been developed by the International Committee on Electromagnetic Safety (ICES), which is sponsored by the IEEE. The federal and state governments do not enforce these voluntary standards. The standards are based on studies of electrostimulation (i.e., nerve and muscle responses to the internal electric field [EF] in the body). ICES standards recommend maximum permissible 60-Hz magnetic field (MF) exposure levels that are a few thousand times higher than 0.3 to 0.4 microtesla (μT) (3 to 4 milligauss [mG]). Magnetic fields greater than 0.3 to 0.4 μT are relatively uncommon exposures that are found in a small percentage of homes that have been shown to have a possible association with childhood leukemia based on inconclusive evidence (National Institute of Environmental Health Sciences 1998, 1999; International Agency for Research on Cancer 2002). Unresolved scientific issues concerning health effects of power frequency related extremely low frequency (ELF) MFs were examined extensively by the California Department of Health Services (Neutra et al. 2002) in response to a request from the California Public Utilities Commission. No evidence substantiates a relationship between ELF EFs and cancer (International Agency for Research on Cancer 2002), and the low-level EFs typically found in homes have not been associated with other diseases (National Institute of Environmental Health Sciences 1998; Institute of Electrical and Electronic Engineers 2002). The ANSI/IEEE standards; NCRP recommendations, International Commission on Non-Ionizing Radiation protection (ICNIRP) guidelines, American Conference of Governmental Industrial Hygienists, Inc. (ACGIH) guidelines suggest maximum permissible 60-hertz (Hz) EF levels for public exposure for electric transmission from 4.2 to 10 kV per meter.

3.6.2 Characteristics of Electromagnetic Fields

EMFs occur both naturally and as a result of human activity. Naturally occurring EMFs include those caused by weather and the earth's MF. EMFs also are generated by technological application of the electromagnetic spectrum for uses such as the generation, transmission, and local distribution of electricity; electric appliances; communication systems; marine and aeronautical navigation; ranging and detection equipment; industrial processes; and scientific research.

EMFs are described in terms of their frequency, or the number of times the EMF changes direction in space each second. Natural and human-generated EMFs encompass a broad frequency spectrum. In the United States, the electric power system operates at 60 Hz, or cycles per second, meaning that the field

[1] See Section 3.0, Introduction, for an explanation of how this section fits together with the HST Network Alternatives presented in Chapter 7, as well as for an overview of the information presented in the other chapters.

reverses its direction 60 times per second. In Europe, some parts of Japan, and many other regions, the frequency of electric power is 50 Hz. Radio and other communications operate at much higher frequencies; many are in the range of 500,000 Hz (500 kilohertz) to 3 billion Hz (3 gigahertz). In areas not immediately adjacent to transmission lines, 60-Hz EMFs exist because of electric power systems and uses such as building wiring and electrical equipment or appliances.

The strength of MFs often is measured in µT or mG. As a baseline for comparison, the geomagnetic field ranges from 50 to 70 µT (500 to 700 mG) at the surface of the earth. Research on ambient MFs in homes and buildings in several western states has found average MF levels within rooms to be approximately 0.1 µT (1 mG), and measured values range from 0.9 to 2.0 µT (9 to 20 mG) in the immediate area of appliances (Severson et al. 1988, Silva et al. 1988).

Depending on the configuration of the source, the strength of an EMF decreases in proportion to distance or distance squared, or even more rapidly. Because the rate of decrease and the distance at which impacts become insignificant depend on technical specifications, such as the source's geometric shape, size, height above the ground, and operating frequency, it is not possible to define a characteristic distance for the extent of field effects that applies in general for all sources. Because of their rapid decrease in strength with distance, EMFs in excess of background levels are likely to be experienced only comparatively near sources. Consequently, only persons on or close to the proposed HST system would be likely to experience such increases, and although HST operations could introduce some very low but measurable changes in 60-Hz MFs up to 1,000 ft or more from the right-of-way, these low-level changes are not known to be harmful or hazardous. ELF is variously defined as having a lower limit of greater than zero (3 or 30 Hz) and an upper limit of 30, 100, 300, or 3,000 Hz. The HST catenary and distribution systems would have primarily 60-Hz fields.

In addition to the 60-Hz EMFs generated by the power supply system, the HST Alignment Alternatives would generate incidental RF fields and also would use RF fields for wireless communications. The 60-Hz electric and MFs from power-supply systems would occur everywhere near the energized conductors, but only the MFs would vary in strength, depending on load. Load would depend on the number of trains in the segment and their operating conditions (acceleration, speed, weight of vehicles, passengers and freight, grade). Hence, in time, the MFs are variable, whereas the EFs are constant. Similarly, EFs along the route would be similar for a given distribution and transmission voltage, whereas MFs along the route would depend on nearby loads. Therefore, daily MF averages would differ for different locales because of different local HST traffic. The information presented in this document concerns primarily EMFs at power frequencies of 50 or 60 Hz and RFs produced intentionally by HST communications or unintentionally by electric discharges (arcing) between the catenary wire and the train's power pickup and other sources of corona discharge typical of high-voltage systems. EMI occurs when the EMFs produced by a source adversely affect operation of an electrical, a magnetic, or an electromagnetic device. EMI may be caused by a source that intentionally radiates EMFs (e.g., a broadcast station) or one that does so incidentally (e.g., an electric motor).

3.6.2.1 CEQA Significance Criteria

For purposes of this discussion, an HST alignment alternative would be considered to result in a significant effect on the environment if it would expose people to a documented health risk associated with EMFs or interfere with implanted biomedical devices.

3.6.3 Environmental Consequences: Past Findings

In the statewide program EIR/EIS (California High Speed Rail Authority and Federal Railroad Administration 2005) EMF/EMI related to the HST Alternative was considered by conducting a search of existing literature and expert opinion (volunteer scientists and engineers from academia and industry working in accordance with IEEE rules) based on that literature. Issues concerning EMF[2] biological and health effects for the HST alternative are the subject of the scientific discipline known as bioelectromagnetics, which is served by the Bioelectromagnetics Society, other scientific organizations, and extensive scientific literature that has been critically reviewed by scientific expert committees convened by a number of national and international bodies. This body of information was used in the statewide program EIR/EIS to describe the potential effects of each of the system alternatives. The medical and scientific communities have been unable to determine whether usual residential exposures to EMFs cause health effects or to establish any standard or level of exposure that is known to be either safe or harmful.

There is no scientific consensus that there are adverse effects of low-level EMFs. Numerous studies have addressed but failed to establish any significant adverse health effects, and various industry, government and scientific organizations with expertise in EMF technology have produced a range of voluntary standards that represent their best judgment of what levels are considered safe. The ELF EMF that would result from the operation of the HST system is substantially below any standards examined by these experts. Consequently, the Authority and the FRA found that, based on review of the scientific evidence and considering the CEQA Appendix G thresholds of significance for effects on human beings, the increased level of EMF as a result of the HST system operation would be less than significant at a programmatic level under CEQA and are not significant under NEPA.

Likewise, the HST system would introduce additional EMI at levels for which there are no established adverse impacts. Extensive studies have failed to establish any specific levels of additional EMI/EMF exposures that result in adverse health effects. The Authority and FRA found, considering the Appendix G thresholds of significance for effects on human beings, that EMI/EMF exposures are not significant at the programmatic level under CEQA or NEPA.

The FRA also has concluded an extensive study of EMF/EMI related to the conversion of a section of Amtrak's Northeast Corridor to electric traction (Federal Railroad Administration 2006) The study quantified the levels of ELF (3–3,000 Hz) EMFs and RF (300 kHz to 50 GHz) electric fields near electric facilities along Amtrak's Northeast Corridor (NEC) between New Haven, Connecticut, and Boston, Massachusetts.

Measurements were taken close to traction power stations and the electric conductors that make up the overhead catenary system on railroad rights-of-way and showed typical increases of one to two orders of magnitude for EMFs from pre-electrification measurements. Other measurements showed that away from the power equipment or the overhead catenary system, very little difference existed between pre- and post-electrification measurements, indicating that the impact on surrounding areas was minimal.

At locations above or under an electrified rail line (overpasses or underpasses), no significant (greater than 1 mG) very low frequency (VLF) (3–30 kHz) or low frequency (LF) (30–300 kHz) MFs were measured. Measured broadband RF electric fields were relatively low, with a maximum measurement of 2% of the FCC occupational standard at 5 m from the track centerline. Also, measured broadband RF electric fields at the overpass and underpass were near zero.

The study characterized the ELF and RF field levels in the passenger compartment and operator's cab of an Acela Express train for comparison with earlier data (1993 Amtrak EMF survey).

> The ELF MF measurements showed significant temporal variability because of operation of the train. This variability is common to all electric transportation systems. The measured ELF electric fields in the passenger compartment were a maximum of 52 volts

[2] EMF covers ELF and RF forms of electric and magnetic fields, and electromagnetic fields.

> per meter (V/m) and average less than 4 V/m. (Federal Railroad Administration 2006, page 3)

The study concluded by comparing the maximum ELF electric and MF readings with exposure limits in the ACGIH and IEEE C95.6 standards.

> None of the limits were exceeded. All RF readings were logged directly as a percentage of the occupational FCC standard. None of the readings were greater than 3% of this standard. Thus, all readings were also less than 3 percent of the IEEE C95.1 and ACGIH occupational limits. Because the general public limits are lower than the occupational by factor of 2.2, the electric field limits for the general public were similarly never exceeded. (U.S. Department of Transportation, Federal Railroad Administration. 2006, page 3)

This study reinforces the conclusion that minimal EMI/EMF exposures at levels for which there are no documented health risks are anticipated and that EMI/EMF concerns are less than significant at the programmatic level under CEQA and not significant under NEPA. Furthermore, the Authority in the CEQA findings and the FRA in the ROD for the statewide program EIR/EIS adopted design practices and mitigation strategies to address potential EMI/EMF issues for the HST system to be applied and refined at the project-level in the future. It is anticipated that the use of the design practices and mitigation strategies will reduce exposure to EMFs and reduce the potential for EMI with biomedical devices to the lowest practical level. These design practices and mitigation strategies are summarized in the following sections.

The prior analysis of alignment alternatives for the HST system considered the diverse geography, communities, and land uses that would be traversed by the system, including the diversity of potential EMF exposures, although very low, in widely varied urban, suburban, rural, agricultural, and industrial areas, and concluded that at the program-level of analysis potential EMI/EMF impacts were not distinguishable among the alignment alternatives. The same is true for this program level analysis of potential alignment alternatives to connect the San Francisco Bay Area and the Central Valley portions of the HST system.

3.6.4 Design Practices

Standard design practices for overhead catenary power supply system substations, transmission lines, and vehicles of the approved HST system include the use of appropriate materials, spacing, and, if necessary, shielding to avoid potential EMF/EMI impacts and to reduce the EMFs and EMI to a practical minimum.

3.6.5 Mitigation Strategies and CEQA Significance Conclusions

Based on the analysis above, and considering the incorporation of design practices, each HST alignment alternative would result in some increase in exposure to EMFs but at levels for which there are no documented health risks. The impact therefore is considered less than significant at the programmatic level. The HST alignment alternatives would have similar extremely low potential for ELF EMFs to interfere with biomedical devices. The impact is considered less than significant at the programmatic level. While EMF impacts are considered less than significant at the programmatic level, in addition to the design strategies described above and out of an abundance of caution, the mitigation strategies described below for avoiding and reducing EMF exposures to a practical minimum will be carried forward for consideration in project-level analyses for the HST system.

- Reduce EMI with catenary components that minimize arcing and radiation of RF energy.
- Reduce potential EMI by selecting RF devices designed for a high degree of electromagnetic capability.

- Reduce EMI with electronic filters.
- Reduce EMI by relocating receiving antennas or by changing antenna design to antennas with greater directional gain.
- Establish safety criteria and procedures and personnel practices to avoid exposing employees with implanted medical devices to EMF levels that may cause interference with such devices.

3.6.6 Subsequent Analysis

The following issues would be evaluated as part of the project-level analysis of an HST system.

- Proximity of occupied structures to new high-voltage transmission lines serving HST substations.
- EMFs at passenger stations.
- EMFs in the vehicle compartment.
- EMFs at specific locations used by the train crew.
- Earth-return currents or power flows in circuits along the rails, where some fraction of the current finds its way back to substation or generating station through the earth for various regions and soil conditions, and the effects of different design and construction practices on these currents. The substations and generating stations themselves would be soundly connected to ground, allowing the earth currents to return there.
- Identification of specific structures (e.g., pipelines, cables, fences) that are particularly susceptible to induced ELF currents and methods for mitigation.
- Identification of receptors (e.g., telecommunications and research facilities) at specific locations with possibly greater sensitivity to EMI impacts.
- Spectral composition of RF generated by the pantograph-catenary contact under operating conditions.
- Technical features (e.g., frequency, field strengths, modulation system) of the right-of-way-to-train wireless communications system.
- Possible development of an electromagnetic compatibility control plan (as described in APTA SS-E-010-98) to characterize EMI sources, reduction techniques, and susceptibility control procedures (shielding, surge protection, fail-safe circuit redesign, changed location of antennas or susceptible equipment, redesign of equipment, enclosures for equipment); inclusion of a safety analysis and failure analysis; and addressing of grounding or shorting hazards.